CS2010 PS6 - Caesarean Section v4

Released: Sunday, 26 October 2014, 8pm
Due: Saturday, 01 November 2014, 8am

Collaboration Policy. You are encouraged to work with other students or teaching staffs (inside or outside this module) on solving this problem set. However, you **must** write Java code **by yourself**. In addition, when you write your Java code, you **must** list the names of every collaborator, that is, every other person that you talked to about the problem (even if you only discussed it briefly). This list may include certain posts in CS2010 Facebook group. If you have access to your seniors' CS2010 files (that is, problem sets version 1/2/3), please refrain from looking at their code verbatim. Any deviation from this policy will be considered as cheating. If the offender is caught beyond reasonable doubt, he/she will be punished severely, including referral to the NUS Board of Discipline. It is not worth it to cheat just to get 19% when you will lose out in the other 81%.

R-option. There is no R-option in this PS. Time to cool down until PS7 =).

2011+2014 Story. This was a scenario that myself (Steven) and my wife (Grace) initially hoped that we did *not* have to go through: a Caesarean section *surgery*. However, Grace eventually had to go through this surgery procedure and we are thankful for the inventor of this technique and current medical knowledge to make this surgery safer.

Caesarean section is an *alternative* method of delivering a baby. It is a **surgical** procedure that involves the obstetrician (the doctor) *'cutting'* through the mother's abdomen, take out the baby, and *suture* the mother back to her original state. Sounds scary? You will probably think so after looking at this video: `http://video.about.com/pregnancy/Cesarean-Section.htm`.

In Singapore, most doctor will by default choose *normal delivery*. Only if there are *known complications* prior to the delivery (e.g. the baby is in breech position, etc) or *unexpected complications* during the attempted normal delivery (e.g. fetal distress, umbilical cord prolapse, etc), then the doctor may offer to perform this alternative delivery method.

As Caesarean section is a surgical procedure, it must be performed *'as fast as possible'* (you do not want the mother bleeds to death or the baby dies). However, it has step-by-step procedures that must be performed one after another (e.g. you have to put the mother on anaesthetic first before cutting her—you do not want to reverse these two steps, etc). Each step has an estimated completion time. Sometimes, nurses, midwives, and/or paediatrician (child doctor) can help do some steps so that the overall surgery time can be minimized to reduce the father's anxiety.

For example, suppose an *over-simplified* Caesarean Section surgery is as follow:

0. The mother is put on anaesthetic, the baby is still in the womb (10 minutes)
1. After step 0, Doctor cuts the mother at the correct spots (15 minutes)
2. After step 1, Doctor takes out the baby carefully (3 minutes)
3. After step 2, Doctor sutures the mother back (30 minutes)
4. After step 2, Nurse cleans the newborn baby (10 minutes)
5. After step 4, Paediatrician measures the newborn baby's birth parameters (5 minutes)
6. After step 3 and 5, present the mother AND baby (both alive) to the father (0 minute)

These 7 steps can be visualized graphically as follows:

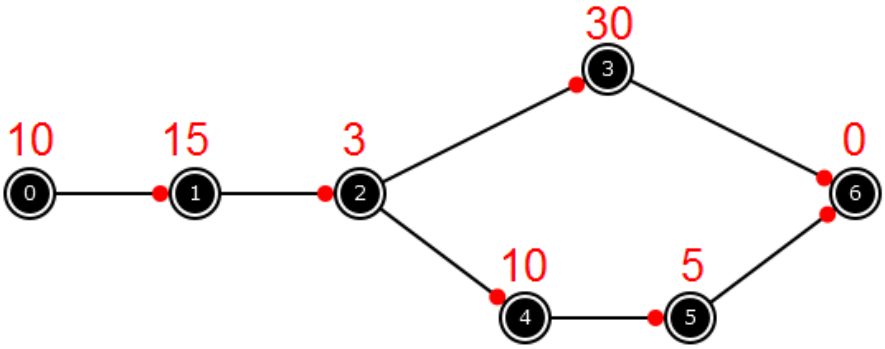

Figure 1: An Over-Simplified Caesarean Section Surgery

In the example above, the start of the surgery is step 0, when the father know the baby is still *inside* the mother's womb and see that the mother is put on anaesthetic. The end of the surgery is step 6 when the father see the living baby *outside* the womb **and** he also see his wife alive. Here, the father has to wait anxiously for 10+15+3+30 = 58 minutes to get **both** good news.

The Actual Problem. Given a dependency information between various steps of a Caesarean section surgery (as a directed graph that will not have a cycle), estimated time to perform such steps (as weights of the corresponding vertices—in minutes), determine the *quickest time* to complete the whole Caesarean section surgery, i.e. from the first step 0 (the mother is put on anaesthetic) until the last step V-1 (the father sees both the mother and the baby alive) can be completed.

Each step can only be performed by one person (usually the doctor). However, if there are two (or more) steps that can be performed by another qualified persons (another doctor, nurse, midwife, paediatrician, even the father, etc), the doctor *can always* call for enough number of helpers to speed up the process while the doctor is taking care on one other step.

The skeleton program `Caesarean.java` is already written for you, you just need to implement one (or more) method(s)/function(s):

- `int Query()`
  You are given an (unweighted) Edge List data structure[1] **EL** that stores the dependency information between various V steps of a Caesarean section surgery. An edge (u, v) in **EL** implies that step u must be performed *before* step v. You can assume that there is always a sequence of steps from step 0 that ends up at step V-1. You can also assume that only vertex 0 has 0-incoming degree in the given graph and only vertex V-1 has 0-outgoing degree. You are also given an array **estT** of size V that stores the estimated time to complete each step (step V-1 always has 0 minute; the other steps have positive minutes no larger than 1000). Examine these two data structures and answer the query as defined in the section that describes 'The Actual Problem' above.

- If needed, you can write additional helper methods/functions to simplify your code.

Subtask A (25 points). In this subtask, the doctor already plan the sequence of steps very carefully so that by executing step 0, 1, 2, ..., V-1, in that order, he/she will be able to complete the surgery successfully without violating any step dependency[2]. The sample shown above (see Figure 1) fits this description. Constraints: $1 \leq V, E \leq 10$.

[1] Already implemented in `Caesarean.java`.
[2] Violation of this step dependency can harm the mother or the baby.

Subtask B (Additional 50 points). In this subtask, the doctor has *not* plan the sequence of steps yet. You have to help him/her plan the surgical steps (so that he/she can ask enough number of other person to help performing some of the steps). Constraints: $1 \leq V, E \leq 10$.

Subtask C (Additional 18 points). Same as Subtask C, but $1 \leq V, E \leq 200000$. As the test data is large, you have to come up with the *most efficient* solution that you can think of.

Subtask D (Additional 7 points). This Subtask uses the same input file as in Subtask C. However, the query part will now report another single integer that represents the answer for **another query**:

Given a dependency information between various steps of a Caesarean section surgery (as a directed graph that will not have a cycle), ***how many individual steps that can be slowed down by 1 more minute that will not change*** *the* quickest time *to complete the whole Caesarean section surgery, i.e. from the first step 0 (the mother is put on anaesthetic) until the last step V-1 (the father sees both the mother and the baby alive) can be completed.*

This query is also important. Knowing that his/her step is not very critical, the doctor/other helpers can choose to slightly slow down in that step in order to reduce the probability of mistakes. It is known that working under stressful condition increases the risk of making mistakes.

In Figure 1, we can slow down step number 4 from 10 minutes to 11 minutes (the other steps remain unchanged) and the father still needs to wait for 58 minutes to get both good news. However, this is not the only non-critical step. In Figure 1, we can also choose to slow down step number 5 from 5 minutes to 6 minutes (the other steps remain unchanged) and the father still needs to wait for 58 minutes to get both good news. Therefore, the answer for this Subtask D query is now 2 instead of 58.

Note: The official test data has been uploaded to Mooshak online judge, but it is hidden from your view. The time limit setting in Mooshak online judge for Subtask A,B,C,D are all 1 second, i.e. rather strict. You are encouraged to generate and post additional test data in CS2010 Facebook Group. Note that `CaesareanVerifier.java` is available but not distributed as it contains partial solution to this PS. Please check for these conditions before uploading your custom test case:

1. The last index of `estT` must be 0 whereas the other indices must be positive but no larger than 1000.
2. The graph must be a Directed Acyclic Graph.
3. Only vertex 0 has 0-incoming degree in the given graph (we start from vertex 0).
4. Only vertex V-1 has 0-outgoing degree in the given graph (we end at vertex V-1).
5. There must be at least one path from index 0 to index V-1.